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THE RELATION OF THE OCULAR NERVES TO THE BRAIN.

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The course which the ocular nerves take from the brain to the muscles of the eye ball is a very long one, and the number of structures they pass is quite large. Therefore it will be necessary, in order to obtain clearness, to divide them into different sections, of which the divison into the orbital and intra-cranial portions will be the chief one. From the supra-orbital fissure the nerves run along the base of the brain until they reach the brain itself, spreading into the root fibers which end in the ganglia cells of the nuclei, and these are connected by fibers with the cortical centers. Speaking of an ocular palsy, exclusive of diseases of the muscular substance, we have, according to the lesions of the nerve in its different portions, an intra-cranial, orbital, or peripheral paralysis. The intra-cranial is either basal or cerebral and the latter may be either cortical, nuclear or fascicular (Mauthner, die ursaechl. Mom. der Aug. musk.—Laehmungen). By fascicular, are meant those palsies affecting the fibers between cortical centers and nucleus or the root fibers, from which the nerve arises, namely the fibers between nucleus and nerve trunk. Recken (Klin. M. f. A. 1891 p. 349) divides the ocular palsies into central and peripheral, according to the degenerative reaction which is missing in the first case. Then a central lesion would compress only the cortical and fascicular between cortex and nucleus, all the rest would be peripheral. After we have ascertained the site of the lesion, we have to find out the nature of it, whether it is due to an inflammatory process,

to a degeneration, a separation or a compression caused by a morbid process, which may be a tumor, produced by a neoplasm, an aneurism, an accumulation of blood from a hemorrhage, an abscess, a meningeal exudation or to retracting connective tissue pulling or strangulating the nervous elements. Finally, if the cause of the morbid condition creating paralysis of the nerve is determined, for instance, if we know, that it is a tumor of syphilitic origin, the diagnosis will be complete. How far we are able to arrive at this our aim may be illustrated by statistics of Liebrecht from Schoeler's clinic in Berlin (C. Bl. f. p. A. 1891 p. 371): Among 25,000 eye patients, 312 cases of ocular palsies were observed. Seventy of these were under sufficiently long treatment for the collection of careful records, but despite thorough examination by neurologists, and long continued observations, the etiology could be elucidated only in sixty-four per cent. Thirty-six per cent., that is one third, remained unexplained. Hutchinson has reintroduced the term ophthalmoplegia, used by von Græfe in 1869, and calls it internal, if all the muscular structures within the globe, and external, if all or the most muscles moving the eye ball are paralyzed. Mauthner changed them into the words interior and exterior, in order to avoid confusion with paralysis of the internal or external recti, and uses ophthalmoplegia, if muscles of one eye, supplied by different nerves, or if muscles of both eyes are paralyzed. In searching for the site of the lesion, we must study the cerebral origin of the ocular nerves, especially the location of their nuclei.

The nucleus of the third nerve, being the most complicated, has been investigated with particular care in the last few years. 1878, Hensen and Voelckers (v. Græfe's Arch. 24, 1, p. 1.) found, by stimulating different parts of the brain of dogs with the faradic current, that the nucleus of the third nerve occupies the posterior portion of the floor of the third ventricle, commencing above the mamillary bodies and the

floor of the aqueductus Sylvii to the region of the posterior corpora quadrigemina. As the most anterior the nucleus of the ciliary muscle, followed by that of the sphincter pupillæ, lies on the floor of the third ventricle, above the mamillary bodies. At the border of third ventricle and aqueduct, below the posterior commissure, are the centers of rectus internus, on the floor of the aqueduct those of the rectus superior and levator, below the anterior pair of the corpora quadrigemina that of the rectus inferior, and below the posterior pair that of the inferior oblique. They state, however, that the position of the three latter is not absolutely certain, on account of the possible errors arising from the insufficient isolation of the faradic current they used in their experiments. 1881, Kahler and Pick (Prag. Z. f. H. II, 4. p. 301,) from two pathological anatomical investigations observed the same in regard to the interior muscles of the globe, namely, that their nerves originate from the most anterior root fibers of the oculomotor nerve, but in regard to the exterior muscles, they found in a case of paralysis of levator, rectus superior, and inferior oblique, the lateral bunch of the posterior root fibers damaged, the medial intact, which reversely, in another case of paralysis of the internal rectus, was degenerated. They located the root fibers of the rectus inferior also in this medial portion. Starr (Jrl. of Nervous and Ment. Dis., 1888,) adopted the same scheme after analysis of twenty cases. 1882 and 1883, von Gudden investigated the nucleus of the third nerve in rabbits with his degeneration experiments. After removal of the corresponding muscles of the eye and tracing the secondary degeneration of the nerve to its centers, he discovered that each third nerve has two nuclei, a ventral and a dorsal, the former, consisting of two clusters, is the origin of the nerve of the same side, the latter supplies the opposite nerve with crossed fibers. Edinger, Westphal, Darkschewitsch and others worked on the same subject, but the most detailed description was given by Perlia (v. Græfe's Arch., 35, 4,) in

1889. He formulated an anatomical picture of the oculomotor nucleus by numerous sections of the fetal and adult human brain in frontal, sagittal and horizontal directions. It has the shape of an almost regular triangle of broad base, with the greatest sagittal diameter of about ten m. m. and is divided into two, a larger posterior and a smaller anterior portion. The chief group contains four pairs of lateral large-celled nuclei, a single large-celled central and one pair of the small-celled nuclei of Edinger-Westphal. The anterior portion consists of a lateral and a medial cluster, so that all together eight nuclei form the center of the third nerve. He found only crossing of the root fibers of nucleus five and of the fourth nerve, so that Knies takes this as the center of the inferior oblique, which acts in the same sense with the obliquus superior of the other eye.

Pflueger (v. Græfe's Arch. 36,4,) adopts this view of Knies in explaining a nuclear palsy of both obliqui superiores and the right obliquus inferior. Although Perlia thinks that we have not succeeded as yet in proving with certainty by pathological anatomical investigations the connection between any branch of the oculomotor nerve and its nucleus, Knies (Arch. f. Augenh. 1891, 23, p. 45) believes that it can be done with a good deal of certainty by aid of the schemes arrived at by Hensen and Voelckers, Kahler and Pick and Starr, but he places the nucleus of the sphincter before that of the ciliary muscle. Perlia advocates, however, the assumption that the posterior longitudinal fascicule connecting the oculomotor center with the medulla oblongata, forms a connecting link between the nuclei of the third, fourth and sixth nerves. He detected another system of nervous fibers reaching the oculomotor center from above and joining it with the reticular substance of the foot of the peduncle, the function of which is not known yet. Perhaps the cortical fibers of the third nerve originate from them according to Obersteiner (Anleitung, etc., 1892, p. 367). The larger portion of the root fibers runs in a lateral direction to

the posterior longitudinal fascicles, forming thicker branches beyond them, the remaining ones, mostly from the dorsal nucleus, run downwards to the median line, in which they cross to the other side. Siemerling (Chron. progr. Laehmung der Aug. musk. 1891), who examined microscopically the nuclei of the ocular nerves in eight cases, which had been observed very closely clinically, could not decide the question in regard to the crossing of the root fibers and the function of the lateral and medial groups. But he places with some probability the center of accommodation and iris in the anterior, and those of the muscles raising the eye ball in the posterior lateral nuclei. As a new discovery he describes a congeries of ganglia cells in the posterior longitudinal fascicle on the level of the nucleus of the fourth nerve, which he always found intact, when ptosis was absent, so that it probably presents the center of the levator. Mendel (Berl. Klin. W. 1887, p. 913) localized the center of the upper or so-called ocular facial nerve in rabbits and guinea-pigs in the posterior portion of the oculomotor nucleus. He removed the frontal muscle and the upper and lower lid, in order to destroy the orbicularis completely and found later atrophy of the posterior portion of the oculomotor center, but the facial nucleus in the medulla intact. He concludes that the fibers of this nucleus, representing the ocular portion of the facial nerve, run in the posterior longitudinal fasciculi to the nucleus of the facial nerves and unite with peripheral fibers, recognizing in this arrangement an analogy with the spinal nerves noticed in polio myelitis, that in the center fibers of muscles of associated function are united terminating in entirely different peripheral nerves, so that in man perhaps the same formation of the facial nerve exists.

This theory would easily explain the fact, that in bulbar palsy only the lower facial branches participate, since the bulbar palsy does not extend so far upward as to reach the nucleus of the oculomotor and, consequently, of the upper facial

nerve. Birdsall (Jrl. of Nerv. and Ment. Dis.) observed a case of ophthalmoplegia exterior with paralysis of the muscles supplied by the third nerve, in which the excitability of the orbicularis and frontal muscles was impaired. This would also correspond to Mendel's hypothesis for the human brain, but the proof by a post-mortem examination was wanting.

The origin of the fourth nerve is close behind the oculomotor center, and in frontal sections, below the anterior portion of the posterior part of the corpora quadrigemina. The root fibers run backwards to the anterior velum medullare, where most of them cross to the other side. The nucleus communicates with the brain by the raphe, with the anterior corpora quadrigemina and the posterior longitudinal fascicle. In Siemerling's (C. Bl. f. A. 1891, p. 247) opinion it is not a continuation of the oculomotor center, at least not as was generally accepted so far. The nucleus of the sixth nerve lies in the dorsal region of the tegmentum next to the facial knee, and contains large star-shaped cells, from which the root fibers develop at its lateral portion, run in a dorsal direction in circles and pass through the region of the tegmentum. A part of them take a median course and cross. The fibræ arcuatæ connect it with the brain, crossing in the raphe, and go in a vertical course to the pyramidal tracts. Other fibers communicate by the posterior longitudinal fascicles with the oculomotor center. The results of the latest researches on the nuclei of the ocular nerves were given in some detail, as of the cerebral palsies the nuclear is the most important. According to Mauthner the progressive paralysis of the ocular muscles in most cases is caused by a nuclear lesion. Ophthalmoplegia exterior must be nuclear under all circumstances (if not orbital). Therefore the integrity of the interior muscles of the eyeball is a very valuable symptom in the diagnosis of nuclear paralysis. This can happen only if the lesion attacks the branches of the third nerve at a place where they are separated, and that is in the nuclei. The explanation of this

peculiar fact, that in such a small range as the center of the oculomotor nerve some nuclei should be diseased, the others not, was given by Heubner (C. Bl. f. d. med. W. S. No. 52, 1872). He proved that at the base of the brain the small arteries form no anastomoses and are terminal vessels, supplying a very limited portion of the brain substance.

The ramus communicans posterior supplies only the nuclei of sphincter iridis and ciliary muscle, so that the arterial area of these is perfectly isolated from the other oculomotor centers. Therefore ophthalmoplegia interior must be nuclear too. But clinical experience has shown that both forms may occur, simultaneously or one after the other, and that nuclei of other cranial nerves may be involved, if the morbid process, affecting at first only a small portion of the gray substance in the walls of the third ventricle, extends forwards or backwards. In this way a disease of the nuclei of the exterior muscles may reach the optico-pupillary center in the walls of the third ventricle and abolish the reaction of the pupil to light, without damaging the center of sphincter or that of accommodation. Or the center of the sphincter may be destroyed with immobility of the pupils, but the accommodation be preserved. Or the latter may be reached also, so that we have a total paralysis of the third nerve. Then the nuclear lesion has to be diagnosticated from the complications. In other cases the degeneration starting from the most anterior nucleus, being that of accommodation, and travelling downwards, may involve the centers of all the following cranial nerves and finally reach the anterior (motor) cornua of the spinal cord, resulting in progressive muscular atrophy. Another form of nuclear palsy is uncomplicated paralysis of the oculomotor nerve with myosis described by Fontan (Mauthner l. c.) in a case of nicotin-intoxication, the nicotin paralyzing the nuclei of the exterior, and at the same time irritating the nuclei of the interior muscles.

Paralysis of the third nerve with simultaneous maximal dilatation of the pupil may be due to a basal or nuclear lesion, by paralysing the oculomotor nerve and irritating the more resistant sympathetic fibers, by compression, either at the superior orbital fissure or in the walls of the third ventricle, the irritation of which caused mydriasis in the experiments of Hensen and Voelckers. Although anatomical researches in regard to the ocular nuclei have proven a partial crossing of their fibers, so that a unilateral nuclear paralysis would not be very probable, Mauthner infers from clinical observations, that the ocular nerves of each eye have all their nuclei on the same side, and that monocular total ophthalmoplegia is caused by a successive disease of the nuclei of the same side as in the scheme of Kahler and Pick. Eissen (Kl. M. f. A. 1890, p. 277) supports this assumption in opposition to Boettiger (Arch. f. Psych. 1889). An isolated or partial palsy of any ocular muscle, as observed in locomotor ataxia, disseminated sclerosis, and progressive paralysis of the insane, are nuclear. They may be very slight and transient, and as, for instance, mydriasis may be the precursor of these diseases for many years. The nuclear character of isolated palsies of the exterior muscles may sometimes be determined from the accompanying symptoms.

In diabetes they are probably caused by hemorrhages in the nuclear region. Somnolence is another important symptom of nuclear palsy. Mauthner (Wien. med. W. 1891, No. 26 & 27) places the seat of sleep in the gray matter surrounding the central ventricle, in the upper region of which the nuclei of the third nerve are situated, and describes ptosis and paralysis of internal rectus as the focal symptoms of sleep. Headache and pain in the eye may be present or absent in nuclear palsy. Wernicke and Moebius (Berl. K. W. 1884, No. 38) attribute it to irritation of the descending root of the fifth nerve, which contains the sensitive fibers of the eye and the dura mater. The manner in which the paresis sets

in is characteristic for a nuclear lesion. Before it is complete, the movements are slow, as if in wax, and the palsy can be overcome by an energetic mental effort, or it changes in the course of a day; the ptosis, for instance, is less marked in the morning than at night. This shows clearly the origin in the nuclear cells; if not entirely destroyed, they can be influenced by an impulse, which would be impossible, if it were in the nerve itself and the conduction interrupted. The nuclear palsies are not associated, as, for instance, nuclear paralysis of both abducentes was observed. If they last for a time, no double images are complained of. Very different morbid processes may cause nuclear paralysis. Congenital ptosis, for instance, with functional impairment of rectus superior and obliquus inferior is due to a malformation in the nucleus, (Mauthner, p. 377), traumatic hemorrhages into the nuclei, tubercles, compression of the medulla oblongata and of some ocular centers by caries and tumors of the vertebræ. The most common causes are ependymitis, with secondary sclerosis extending into the gray substance around the ventricles, multiple sclerosis and atrophy of the ganglia cells. The nuclear ophthalmoplegia may be congenital or acquired in the first years after birth, without any other disturbances, or it may develop in adults and remain stationary, without other cerebral symptoms. But it may be complicated with headache, paralysis of other cranial nerves, bulbar palsy, locomotor ataxia, progressive muscular paralysis and mental diseases. In cases of acute or sub-acute development it may be fatal by its complications, or heal and recur, or remain stationary.

Our knowledge of the cortical lesions of the ocular muscles is still very limited, since the cortical centers are not explored beyond doubt. What we know of them is mostly obtained from experiments in animals, consisting in the stimulation of the cortex by faradic currents. Hitzig placed the cortical center of the ocular muscles in the frontal lobe,

Hensen and Voelckers in the temporal, Ferrier in the angular gyrus and Munk in the occipital lobe.

Recent experiments of Munk (C. Bl. f. A. 1890, p 149) on dogs confirmed Schaefer's investigations on monkeys, that stimulation of the visual center with weak faradic currents elicits associated ocular movements of the opposite side, the eyes turning downward, if the anterior, and upward, if the posterior area of the visual sphere is stimulated. Ocular movements never occurred if a spot outside the visual sphere was irritated. Munk explains these facts by the supposition, that the fixation of the eyes is instituted by perceptions of light, by which stimulation of the radiant fibers of the corona ciliaris is propagated to subcortical portions of the brain. These fibers govern the involuntary movements of the eyes, which we perform in order to find the right fixation of objects we noticed only indistinctly before, and are to be considered as congenital reflexes, as the lowest visual reflexes dependent upon perception of light, not on visual impressions. They are a great help for the quick and reliable perception of the visual field. The fibers of association which connect the visual spheres with the cortical motor centers of the ocular movements, govern the higher visual reflexes. Knies, (l. c. p. 24.) assumes two different cortical spheres for the voluntary innervations of the ocular muscles. First, the visual sphere for the voluntary movements of the eye, convergence and accommodation, and second, the so-called motor cortical region of the levator. He acknowledges the involuntary character of the ocular movements obtained by Schaefer and Munk, but they run in the same tracts in which the voluntary impulses to ocular movements are physiologically conducted to the muscular nuclei. All voluntary ocular movements starting from the visual cortex are conjugate and tend to binocular fixation. The visual cortical center of each side governs chiefly the voluntary conjugate movements of the eyes to the opposite side. The area of the visual sphere corresponding

to the macula is the cortical center of the voluntary convergence and accommodation of a fixed object and it may start innervations for voluntary movements in all directions. Each visual sphere is connected chiefly with the nuclei of the third and fourth nerve of the same, and with that of the sixth nerve of the opposite side. All voluntary ocular movements are conjugate, therefore all disturbances of them are conjugate.

These quotations will sufficiently show how difficult a definite diagnosis of cortical or fascicular paralysis will be, so far as the fibers between cortex and nucleus are concerned. If a paralysis of the exterior muscles supplied by the third nerve is associated with contralateral hemiplegia, the lesion must be fascicular, and is located in the pedunculus cerebri, in which the exterior fibers coming from their nuclei behind and the interior fascicles from in front are still separated, as proven by two post-mortem examinations of Kahler and Pick. If exterior and interior muscles are affected, the focus must be near the exit of the nerve, where they unite, or it may be basal and be caused by two different lesions. Paralysis of the sixth nerve with contralateral hemiplegia is due to a focus in the pons. In regard to the differential diagnosis between these three kinds of cerebral palsies from the basal, we have only one symptom which is absolutely certain, and that is the integrity of the interior muscles, if the exterior are paralyzed. This never happens in basal lesions. The recurrent paralysis of the oculomotor nerve in most cases is basal. It is characterized by the fact that only one oculomotor nerve is totally paralyzed, and that each relapse affects always the very same nerve, never that of the other side. It heals for awhile, or becomes less in intensity, until after weeks, months, or a year, a new attack occurs, usually commencing with hemicrania and lasting from one day to several weeks and months. It is always acquired in infancy, most likely by an injury of the base of the skull from a trauma of the head, happening so often in children, and subsequent gradually developing pachy-

or leptomeningitis near the trune of the oculomotor nerve. The relapses are explained by transient increased hyperemia (for instance, in females at the time of the menses).

Pel (Berl. K. W. 1890, 1,) observed a case of recurrent partial paralysis of one third nerve of nuclear origin, proven by the integrity of the interior muscles, in the first stage of locomotor ataxia, relapsing seven times. The isolated bilateral paralysis of the third nerve may be nuclear or basal from compression by a tumor or artery at the base or meningitis. Both sixth nerves may suffer by a nuclear disease in the fourth ventricle, by a basal affection at the posterior margin of the pons, or by a symmetrical compression in the cavernous sinus by tumors from increased intracranial pressure. Affection of both fourth nerves may be in the anterior velum medullare and therefore fascicular, or it may be nuclear, as Pflueger observed a case. Sometimes it is very difficult to differentiate a nuclear from a basal unilateral multiple paralysis of cranial nerves, and then the condition of the olfactory and optic nerves becomes very important. Homonymous hemianopia in such cases may be nuclear or basal, as the lesion may be situated in the thalamus opticus and then be nuclear, or in the tractus opticus and, then be basal. Amaurosis of the eye of the same side alone or with temporal hemianopia of the other eye can be only basal. In the first case it can only happen by compression of the optic nerve at the base after it has left the chiasm, and in the second case optic nerve and tract of the affected side are damaged.

The affection of the olfactory nerves in multiple paralysis of cranial nerves shows generally a basal cause, but in nuclear paralysis, anosmia may be due to a disease in the bulbus olfactorius. Nuclear and basal palsies may occur simultaneously from the same cause, for instance by a tumor of one hemisphere paralyzing the anterior cerebral nerves by pressure at the base and by hydrocephalus of the fourth ventricle compressing the nuclei at its floor. Bilateral progressive paralysis

fo cranial nerves is in most cases nuclear, the diagnosis resting chiefly on the condition of pupil and accommodation. Blindness of both eyes without ophthalmoscopic changes or with simple atrophy of optic nerves in such bilateral affections, may be nuclear as proven by autopsy, or basal caused by strangulation of retracting tissue from a partial chronic basilar meningitis. The peculiar fact was observed in autopsies, that the nerves at the base, even if apparently destroyed, for instance, when perfectly flat by compression or imbedded in inflammatory growths or tumors, do not show sometimes any degeneration of their fibers, so that their functional disturbance must be explained by an ischemia of the vessels of the nerves.

The causes of basal palsies may be of various kinds (according to Mauthner's synopsis): Hemorrhages, circumscribed pachymeningitis near the nerve trunks. Meningitis of the cortex and the base, the latter mostly tubercular in children. Therefore in children double vision from paralysis of an ocular muscle gives a very bad prognosis. Abscess of the brain, especially of otitic origin; diseases of the basal arteries, as aneurism; arteritis obliterans by want of blood supply of the nerves, syphilitic products and neoplasms growing around and into the nerves. The nerves themselves may be the seat of neuritis, of gummous and tubercular interstitial neuritis and perineuritis, lymphomatous swelling in cases of general lymphomatous and gray degeneration following atrophy of the nuclei.

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